

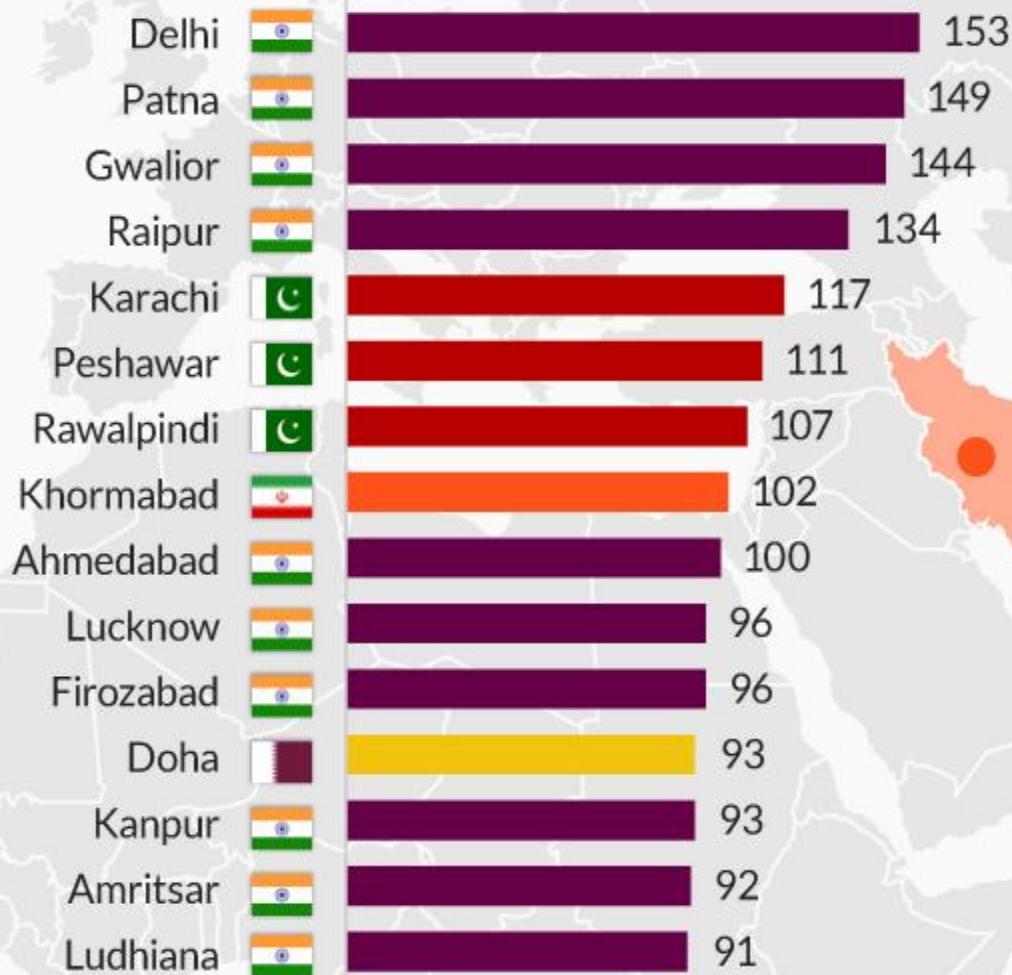
Using Exposure Management to Control India's Health Burden From Air Pollution

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The world's most polluted cities are in India

PM 2.5 (micrograms per cubic meter) in the most polluted cities worldwide in 2014



700 million people caught in the “Chulha Trap”

One-quarter of
world total

Percent of households using biomass as their primary cooking fuel



*Indicates >1% Coal Use

Fig. 1. Distribution by state of households using biomass or coal as their main cooking fuel in 2005. From (IIPS, 2007).

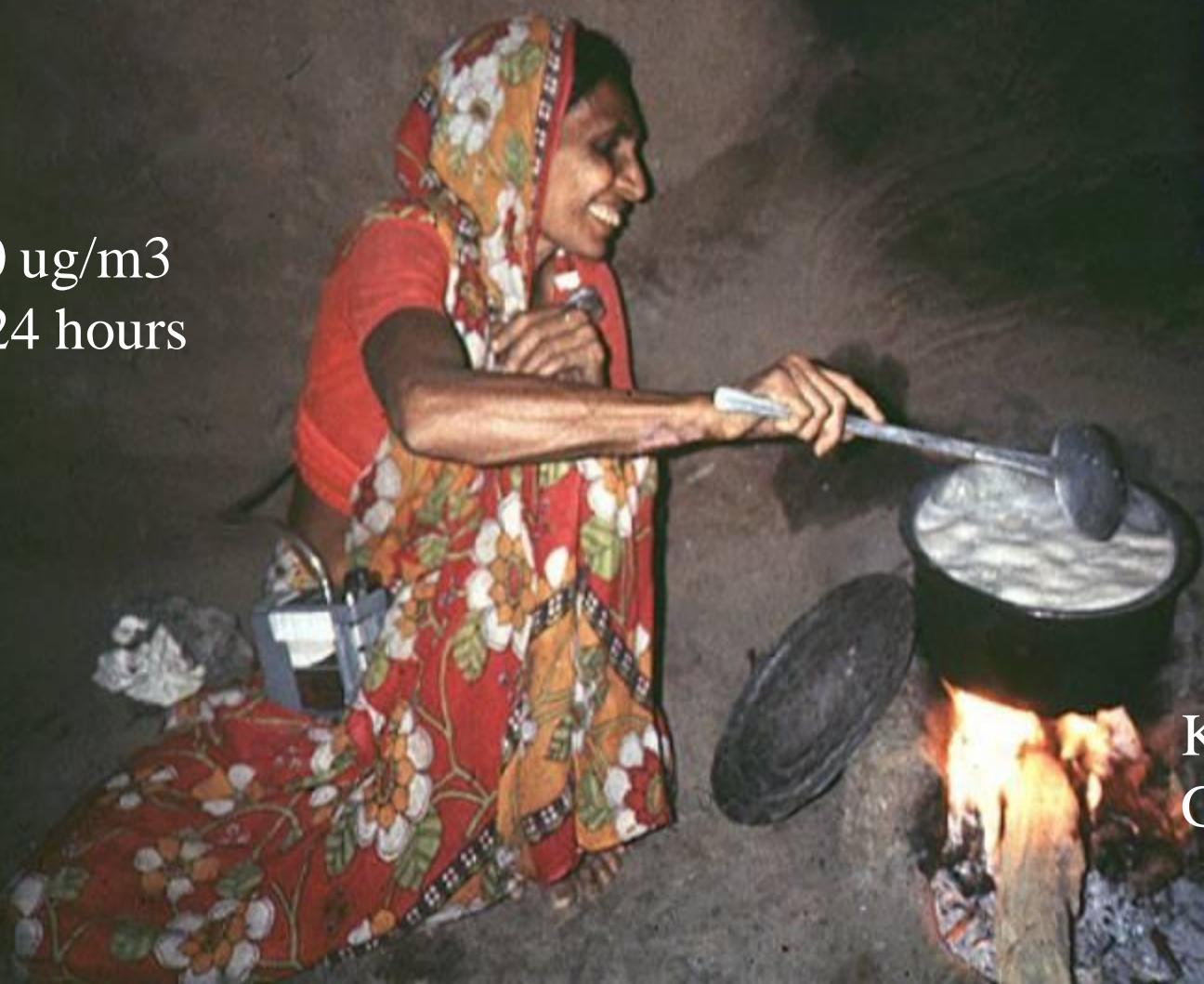
1990:
85%: 700
million people
using solid fuels

Today:
60%: 700
million people

~1980
700 million
people
in entire country

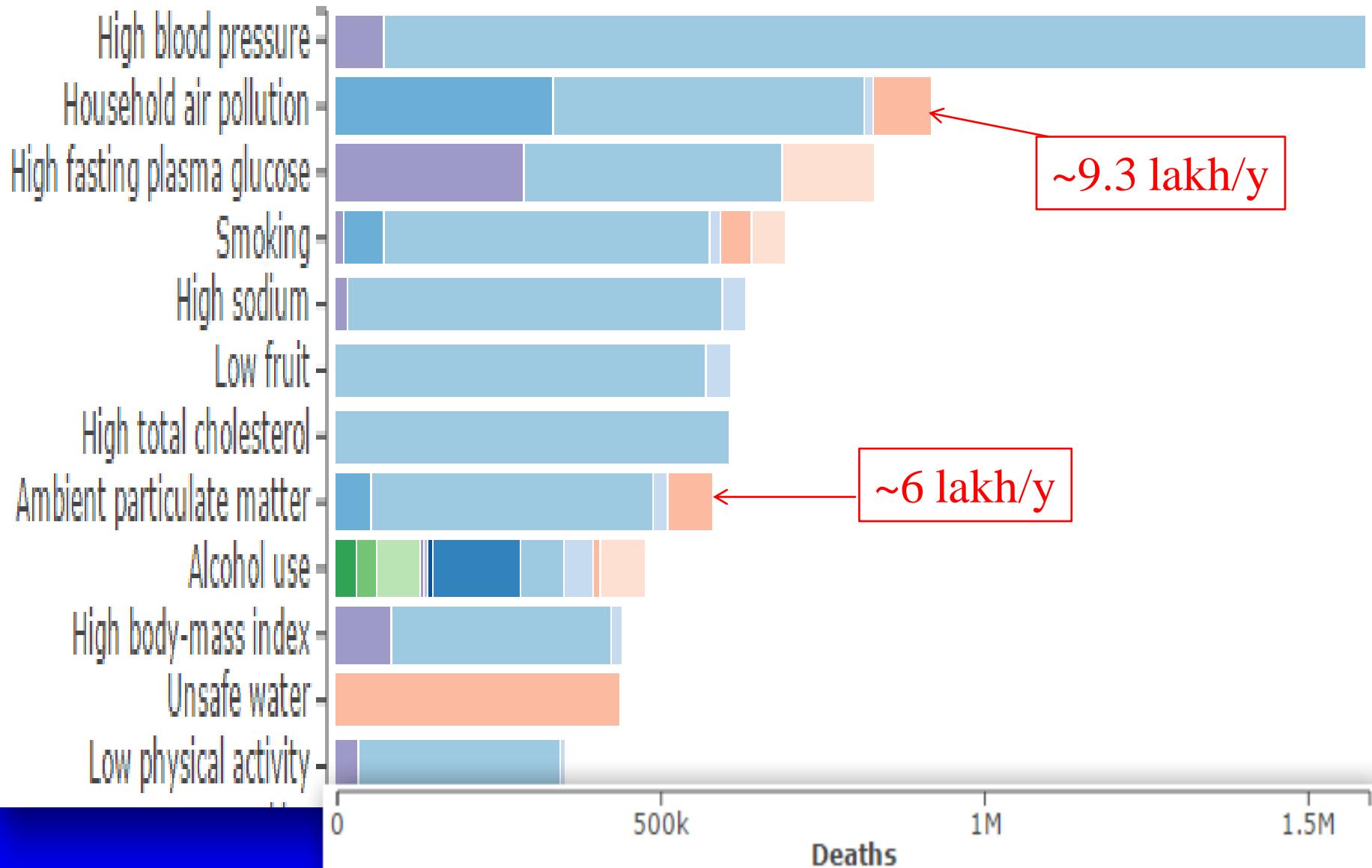
First person in human history to
have her exposure measured
doing the oldest task in human history

~500 ug/m³
For 24 hours



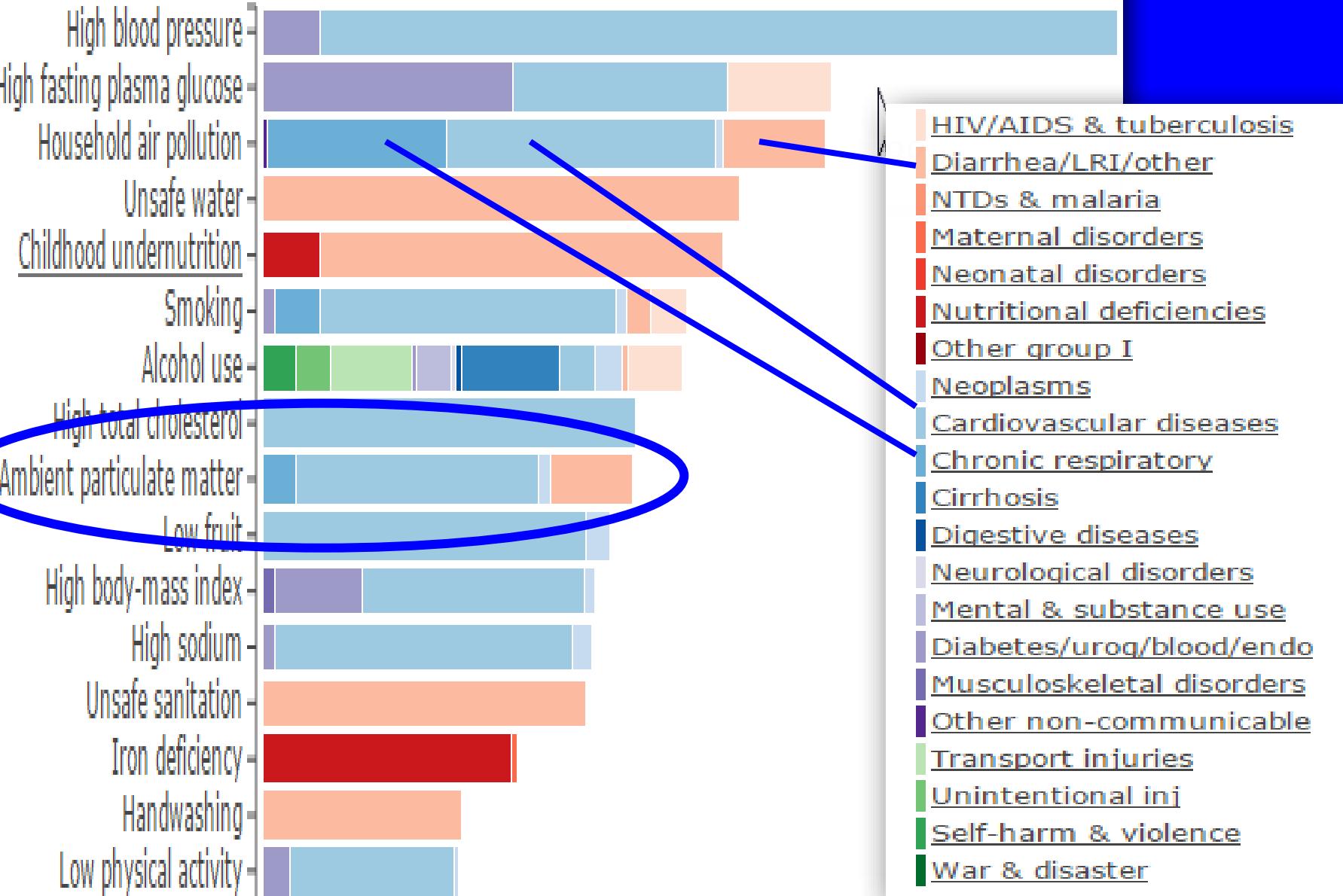
Kheda District
Gujarat, 1981

India, Both sexes, All ages, 2013



DALYs

India, Both sexes, All ages, 2013

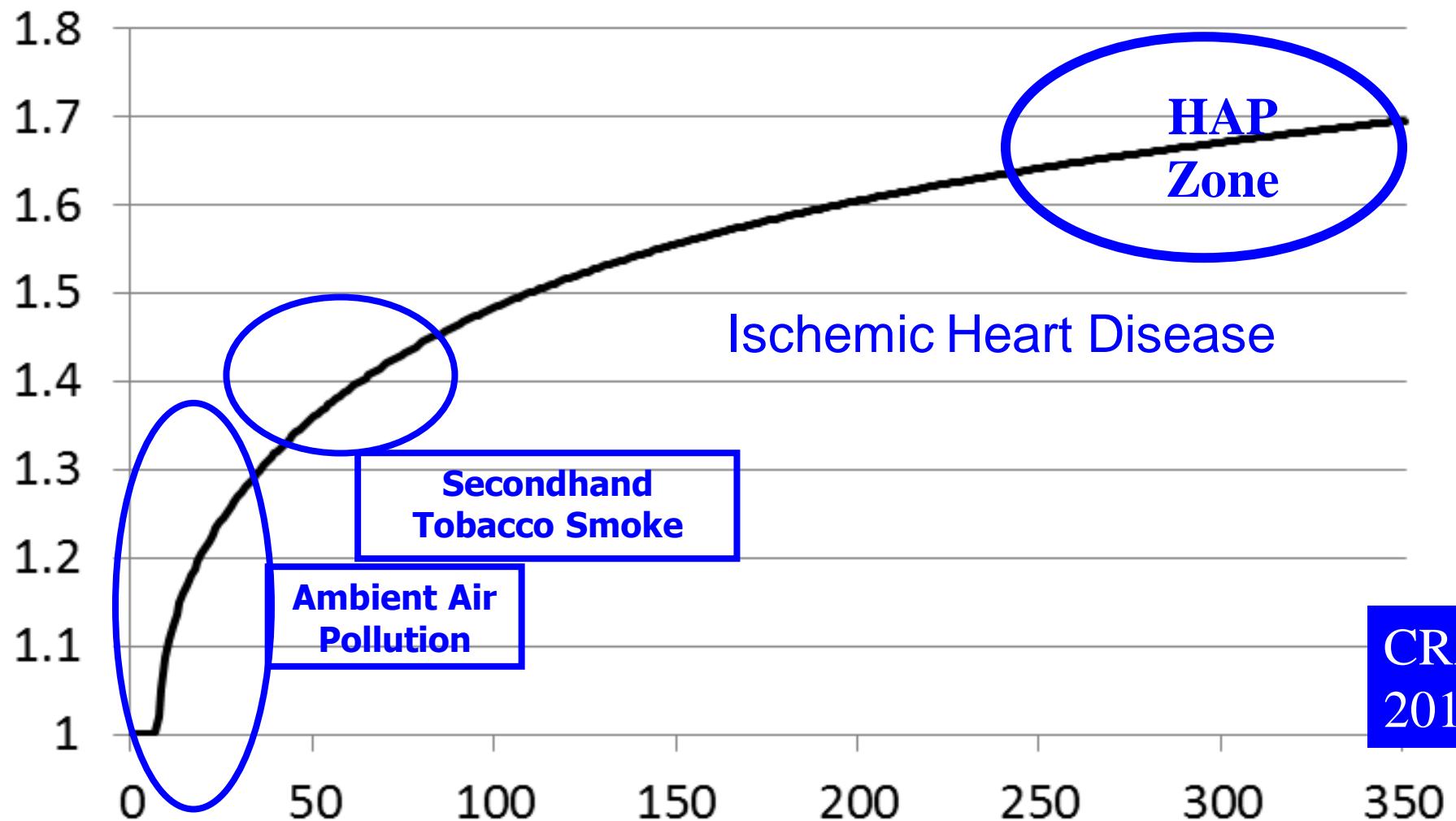


Integrated Exposure-Response (IER)

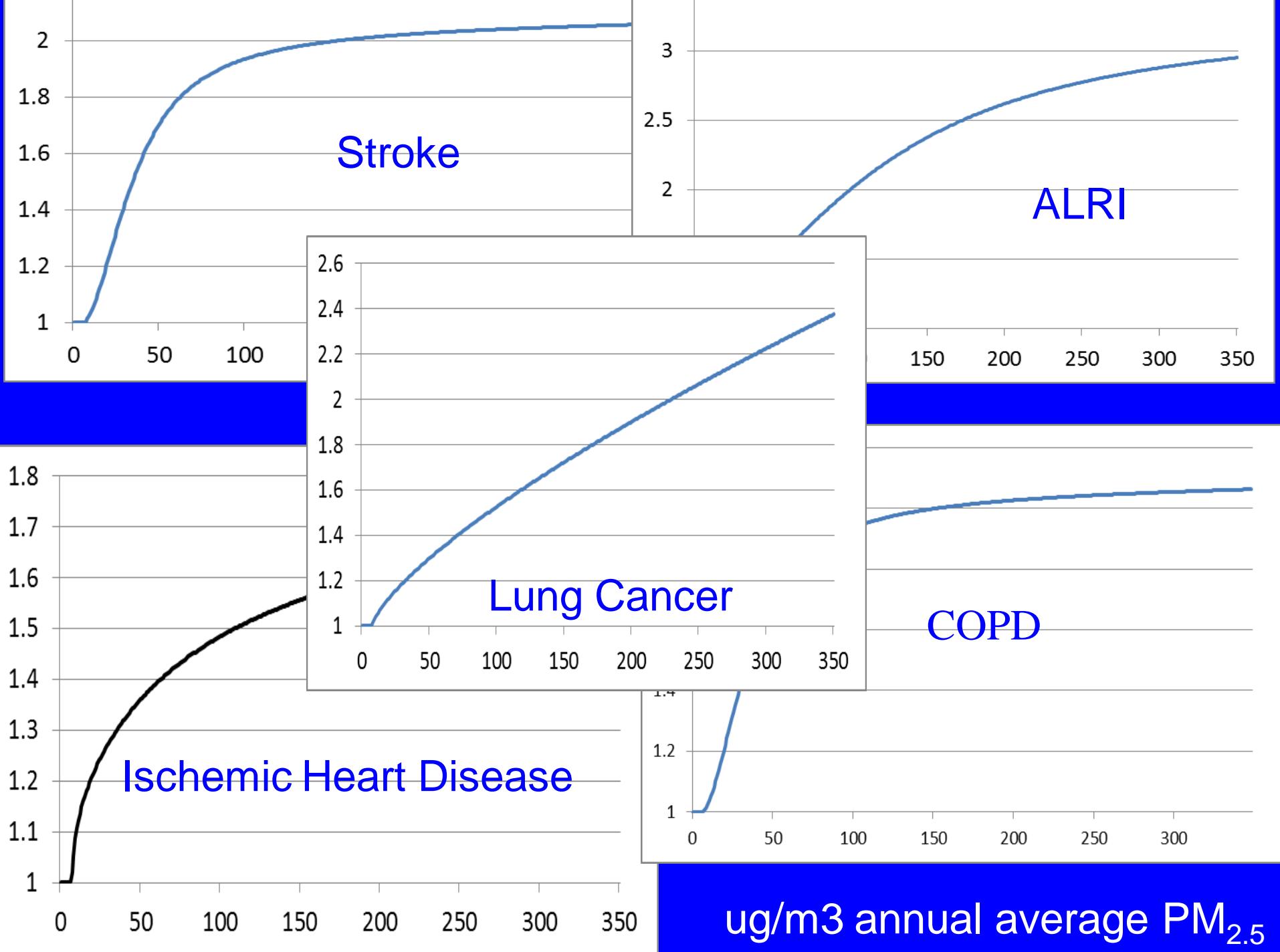
- Combines health effects studies of outdoor air pollution, secondhand tobacco smoke, household air pollution, and active smoking
- Now have IER curves for 5 major diseases caused by combustion particle air pollution
- Bolsters evidence base overall
- And allows for consistent comparisons

Integrated Exposure-Response: Ambient Air, SHS, and Smoking and Heart Disease

Smokers →



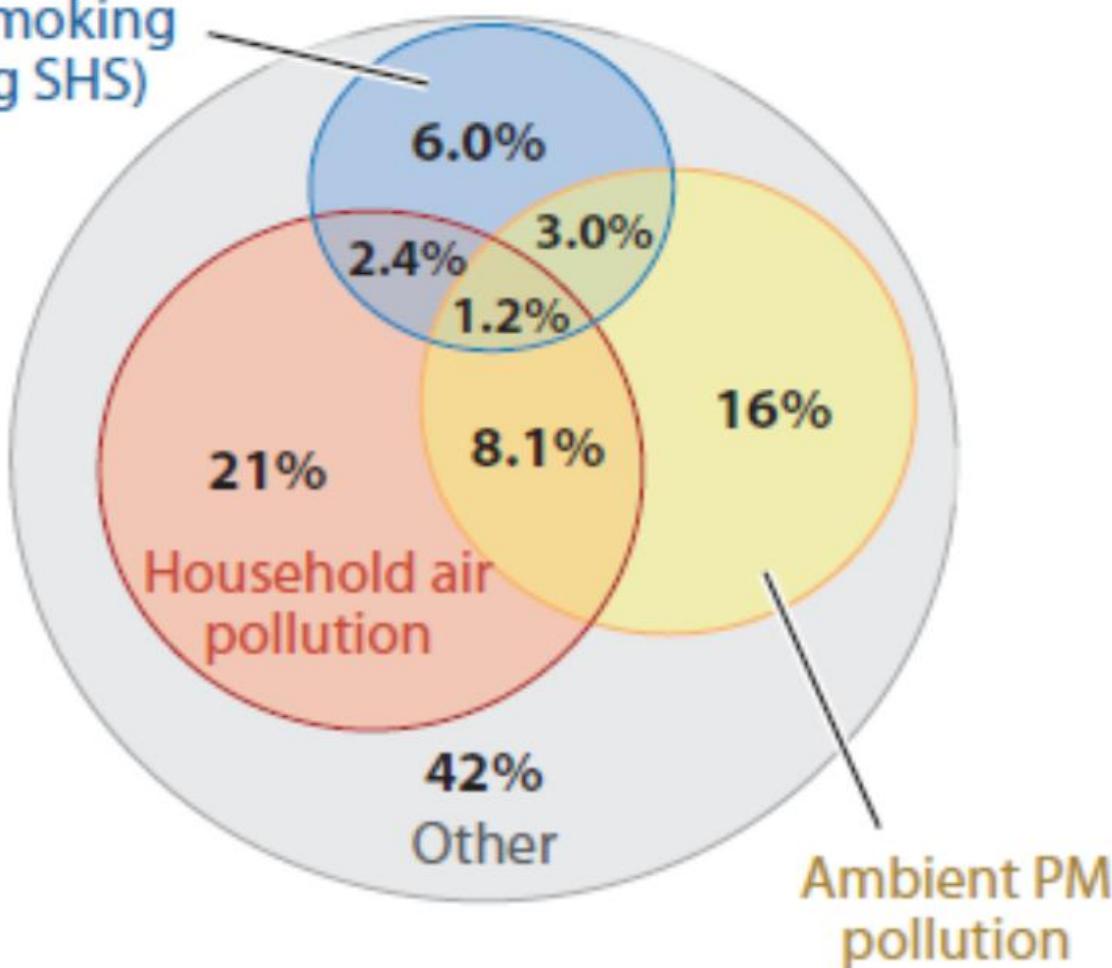
CRA,
2014



India IHD female DALYs

9,090,000 DALYs

Tobacco smoking
(including SHS)

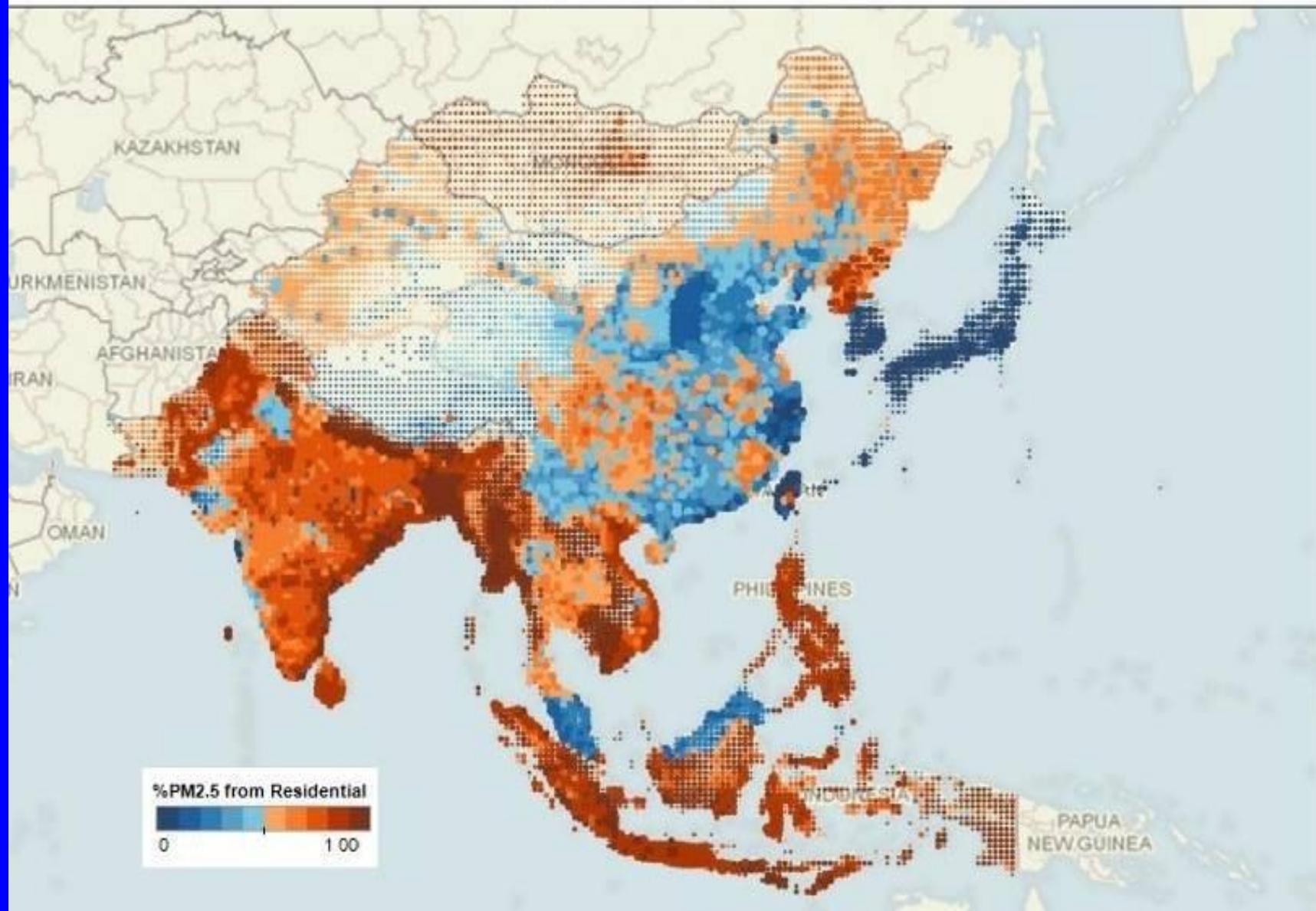


Compared to What?

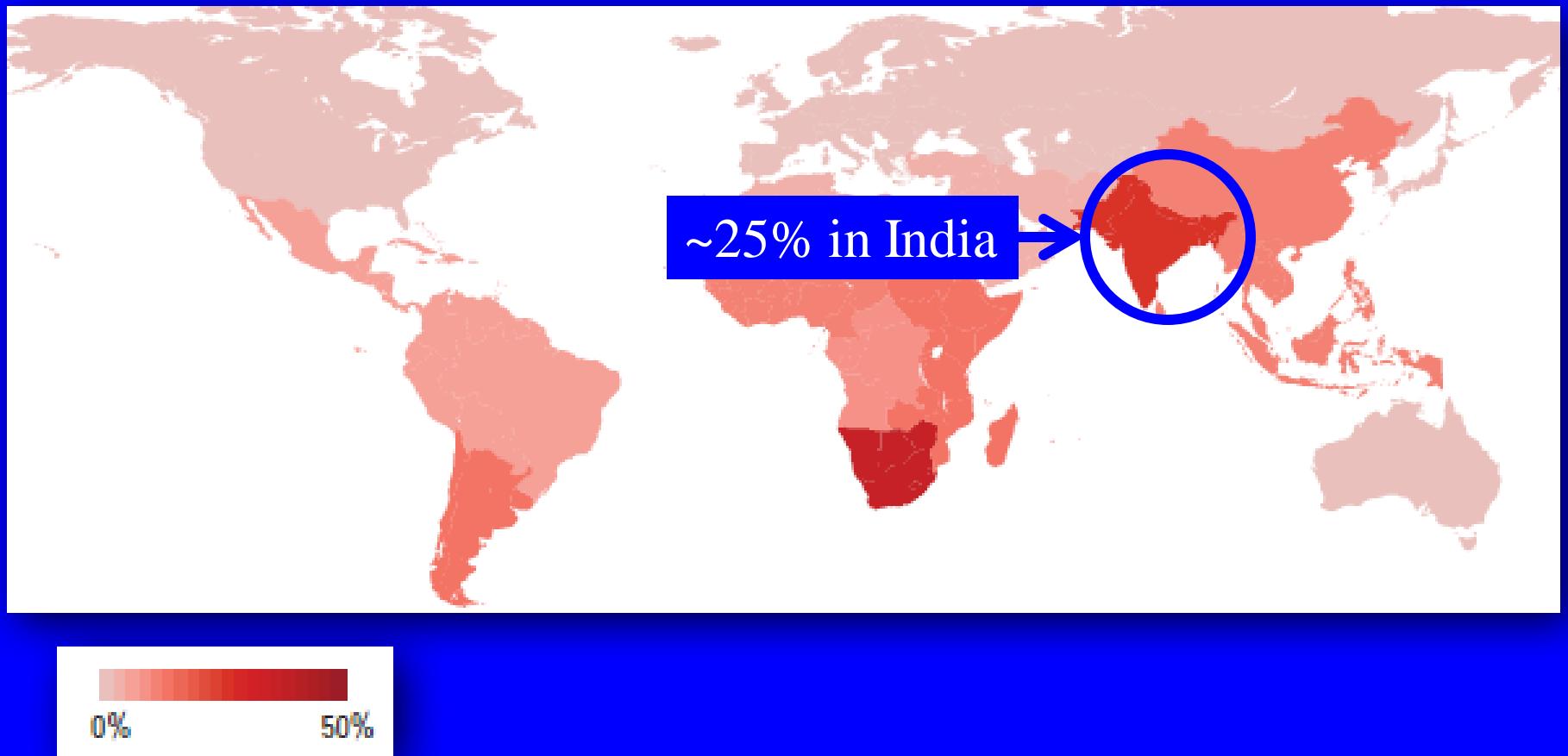
- Ambient air pollution – ~98% cleanest city in the world ~7 ug/m³ PM2.5
- Household air pollution – cooking with gas ~ 7 ug/m³ PM2.5

%PM_{2.5} from “Residential” Emissions : NASA

% of Anthropogenic Primary PM_{2.5} from Residential Sources
(INTEX_B 2006)



Percent of primary ambient PM_{2.5} from household cooking fuels – population weighted



Chafe, et al., 2014

Country	Deaths ($\times 10^3$)	Residential energy
China	1,357	32 (76)
India	645	50 (77)
Pakistan	111	31 (67)
Bangladesh	92	55 (78)
Nigeria	89	14 (31)
Russia	67	7 (18)
USA	55	6 (12)
Indonesia	52	60 (64)
Ukraine	51	6 (13)
Vietnam	44	51 (74)
Egypt	35	1 (2)
Germany	34	8 (17)
Turkey	32	9 (20)
Iran	26	1 (3)
Japan	25	12 (29)
World	3,297	31 (59)

Percent of outdoor air pollution from households in India

Nature, Sep 17, 2015

Household Energy Consumption, Emissions, Pollution, and Health Impacts in India

STATE

Bihar

(state and district as of census-India, 2011)

DISTRICT

Araria

Household energy consumption (HEC) emissions were calculated in four classes - cooking (CK), lighting (LG), space heating (SH), and water heating (WH). Bottom-up emissions for the four classes are available @ 0.25 degree spatial resolution, and further aggregated to district and state level. A sub-classification is available by fuel - biomass, coal, kerosene, liquified petroleum gas (LPG), and others.

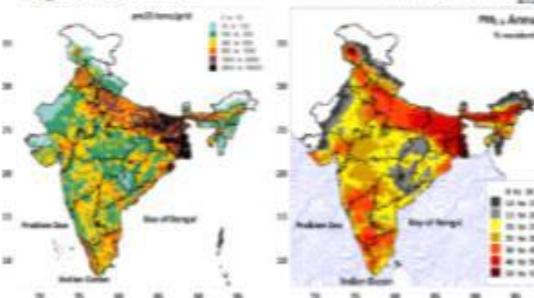
%Households Primary Cooking Fuel

gas+elec	others
3.2%	96.8%

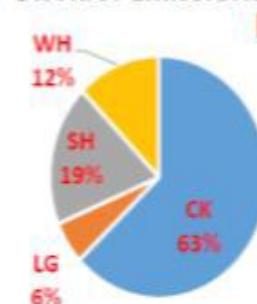
Estimated district annual HEC emissions

Particulates (2.5 μm)	11,780 tons
Sulfur dioxide	840 tons
Nitrogen oxides	1,165 tons
Carbon monoxide	145,400 tons
Hydrocarbons	20,900 tons
Black carbon (BC)	2,530 tons
Organic carbon	4,560 tons
Carbon dioxide (CO ₂)	0.22 mil tons

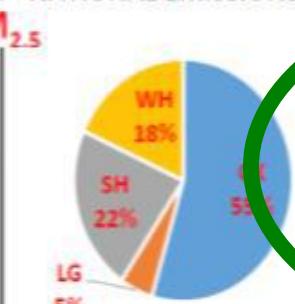
Estimated PM_{2.5} emissions @ 0.25 degree resolution



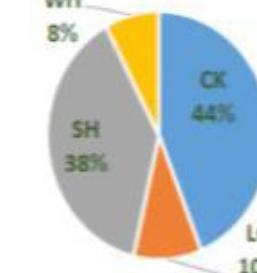
DISTRICT EMISSIONS



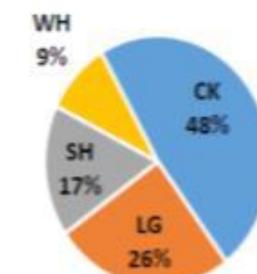
NATIONAL EMISSIONS



CO₂



BC



% contribution of HEC emissions to modeled ambient PM_{2.5} concentrations

National	29.6%
District	38.2%

(concentrations were conducted using the WRF-CAMx model)

The health impacts of outdoor air pollution as ischemic heart diseases (which can lead to heart attacks), cerebrovascular disease (which can lead to strokes), chronic obstructive pulmonary diseases, lower respiratory infections, and cancers (in trachea, lungs, and bronchitis) were estimated using the age-dependent relative risk functions detailed in the Global Burden of Disease study (2013) and dispersion modeling results from this study. The final calculations were conducted at the district level using the population distribution by age presented in

Estimated premature mortality of outdoor air pollution per year - apportioned to HEC emissions

National	59,000 - 72,000
District	136 - 173

Emission and dispersion modeling results, pollution animations, and summary sheets by district and state are hosted
@ <http://www.urbanemissions.info>
Send your comments and questions to
sim-air@urbanemissions.info



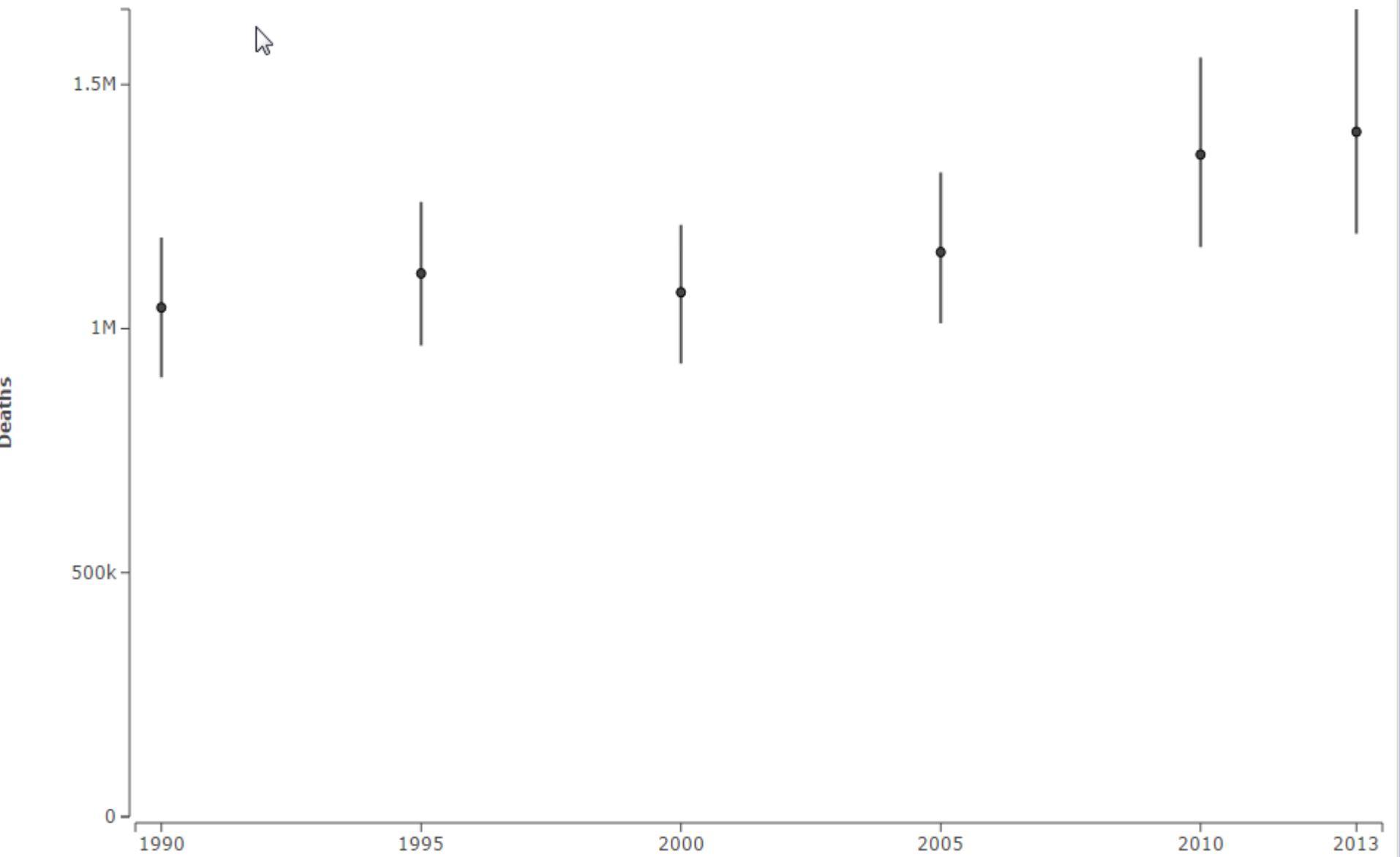
Percent of outdoor air pollution mortality from household fuels

- Varies by model and databases used
- 25-50% in India
- 14-30% globally
- Household sources are as important as any other sector, and sometimes more than vehicles, industries, power plants, etc.

Recent trends give us an idea
where we are going if
nothing is done.



India
Air pollution
Both sexes, All ages



The Environmental Risk Transition

- How do environmental and other health risks trend during economic development?
- Not uniform in every country at every period,
- But broadly the case both historically and in cross section.
- India in a unique place historically

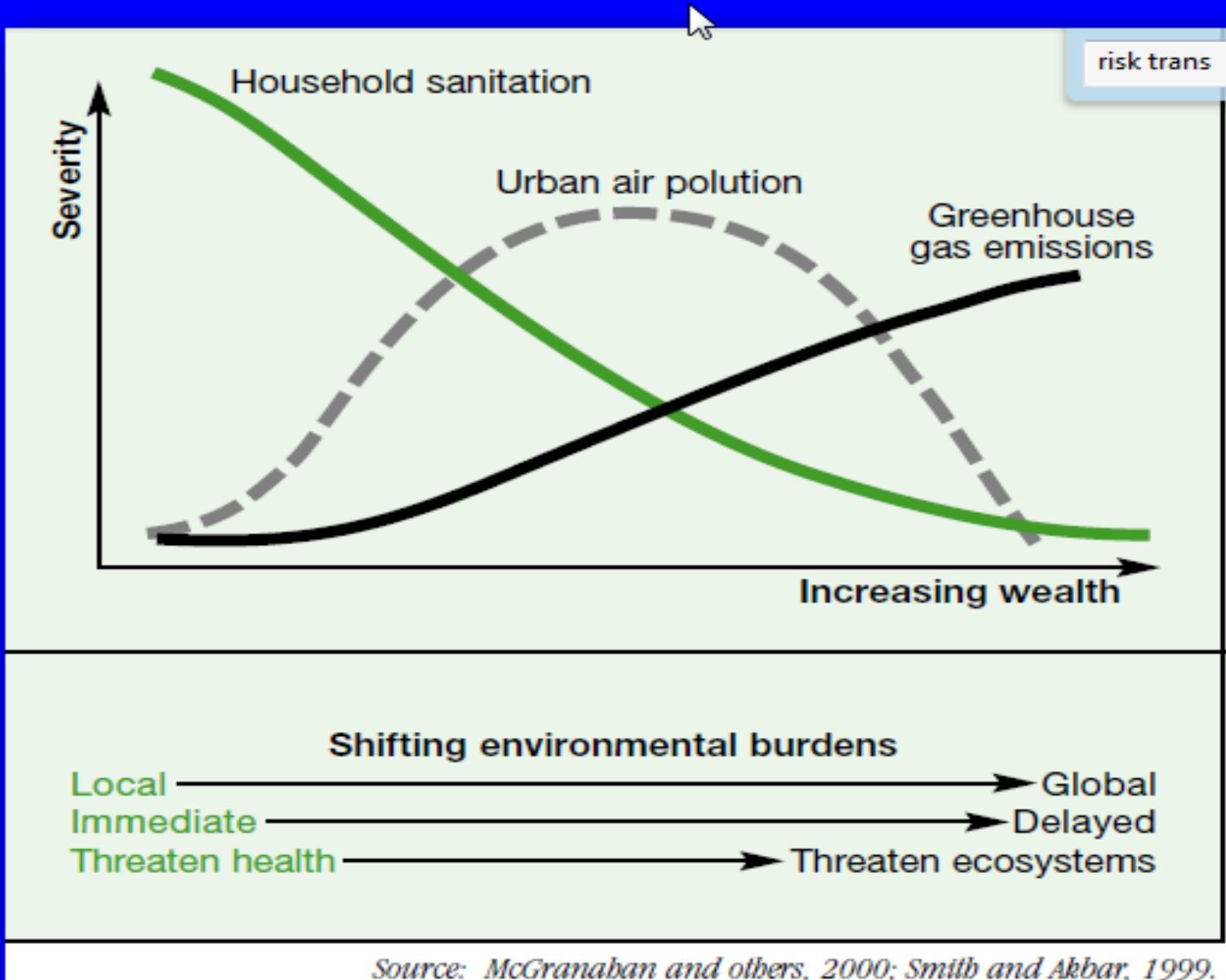
The Environmental Risk Transition



The Environmental Risk Transition



Classic Full ERT



India

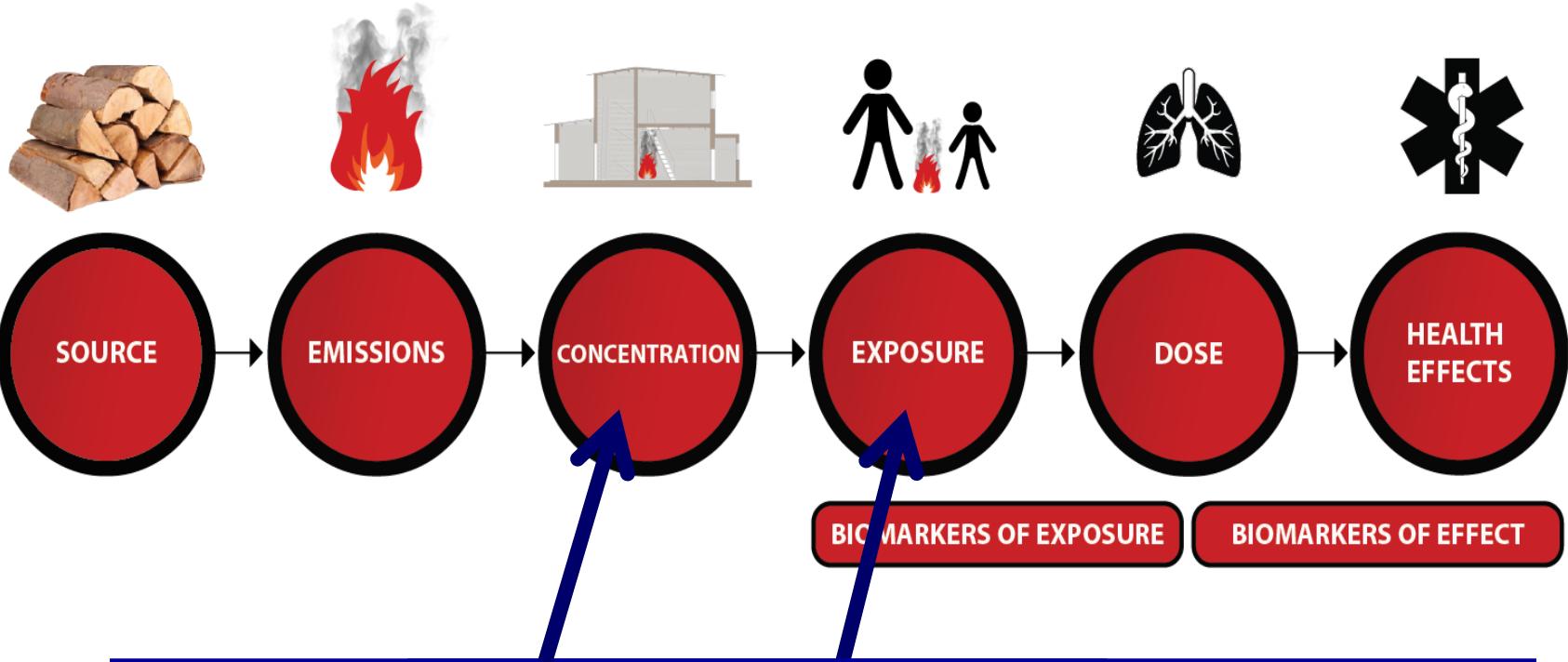
- Still with ~two-thirds of households using solid cookfuels – only part way down the traditional risk curve
- Most polluted cities in the world –peak of the modern risk curve
- Highest burden of disease from air pollution in the world – greatest risk overlap
- Highest total air pollution burden/capita of all middle-income countries – 2x China

Ministry of Health and Family Welfare 2015, “Report of the Steering Committee on Air Pollution and Health Related Issues”

- First Ministry of Health in world to treat AP as one of its major priorities and consider along with other risk factors in its mission
- First government agency in the world not to address AP by location, but by total exposure – a true health focus
- Thus, not indoor/household, not outdoor, but by what will give the most health benefit

Premise

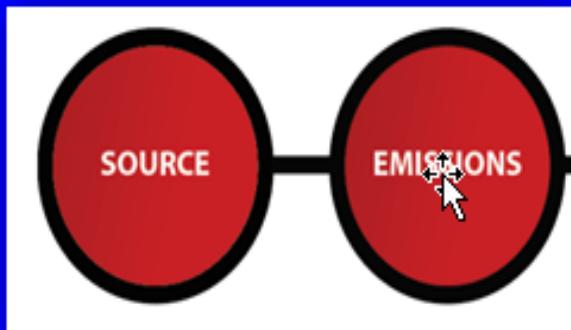
- Eventually, we wish to control all sources of air pollution, all the time, everywhere.
- But we cannot afford to do so immediately
- What metric gives the optimal pathway such that the most health protection is occurring at each stage of investment?
- Only metrics of exposure are a practical way to do so



Classic air pollution research has focused on metric concentration in order to design and controlling

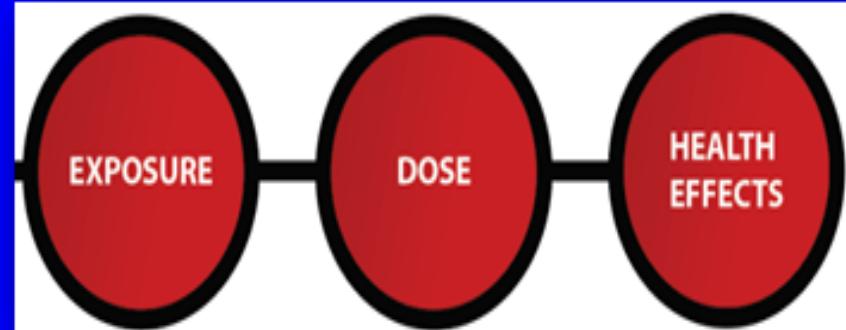
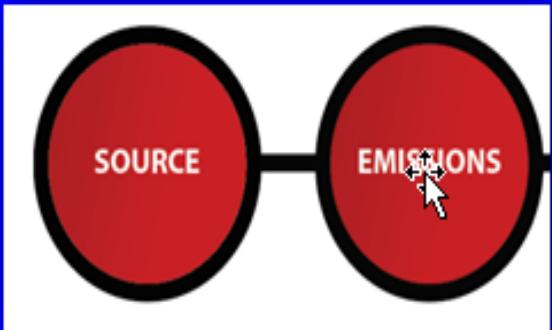
Source – Exposure Relationships

Vehicles

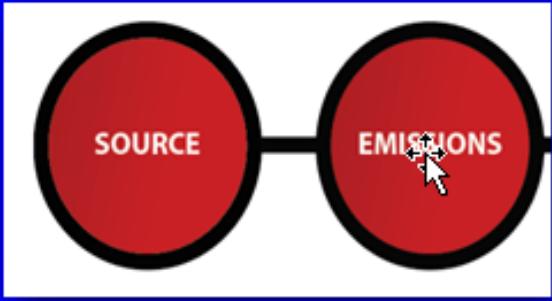


How different?
Does it matter?

Power
plants



Stoves



MoHFW AP Task Force

- Total exposure approach requires utilizing estimates degree of exposure due to each source category.
- Emissions weighted essentially by proximity to population
- Goal is to change source apportionment to exposure apportionment
- Control not in a particular place, but where the people are

Exposure apportionment methods

- Intake fractions by category
- Population weighted personal exposure assessment with source apportionment
- Micro-environmental source apportionment
- Modeling
- Many new tools available including sensor networks, satellite observations, GIS mapping, small/cheap monitors, etc

One Approach is Intake Fraction

IF is the fraction of material emitted
that is actually breathed in by someone

Ranges from 1,000 to 10 ppm
(grams inhaled per tonne emitted)



IF = one million ppm – all is breathed in

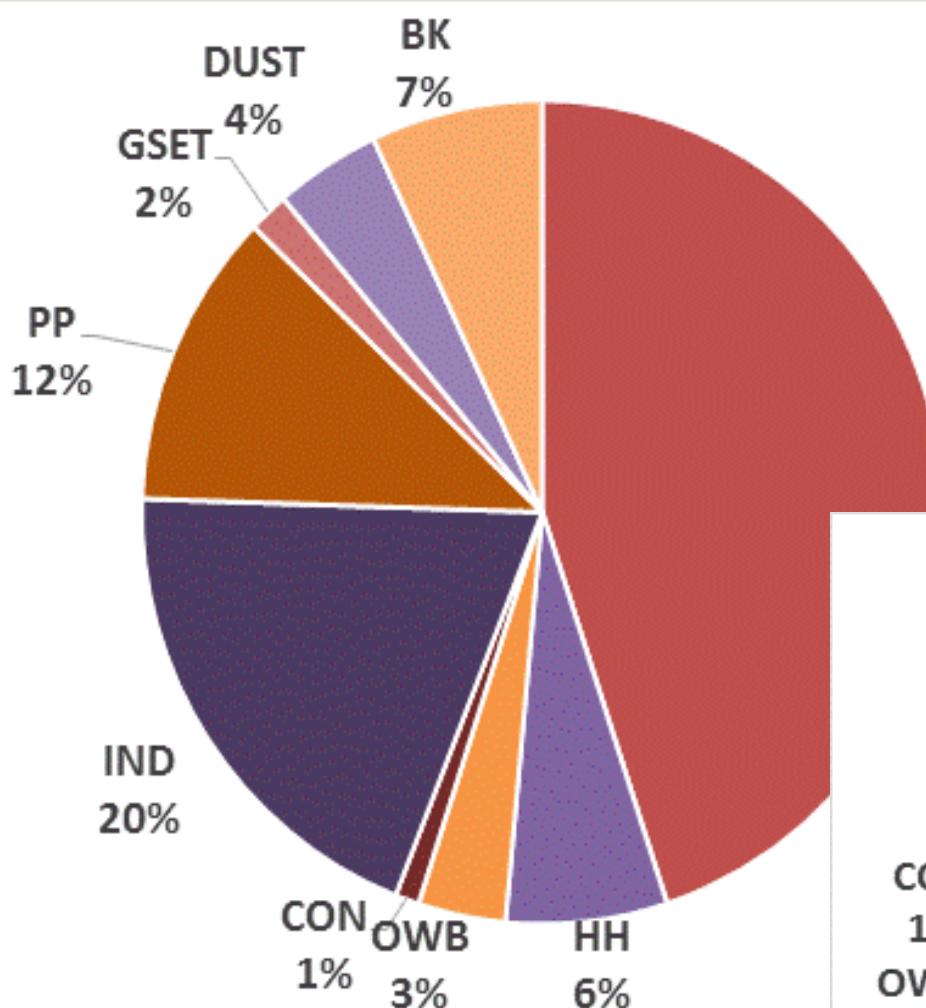
Worse thing you can do

Ambient Intake Fractions in Chennai

ppm – grams inhaled per tonne emitted

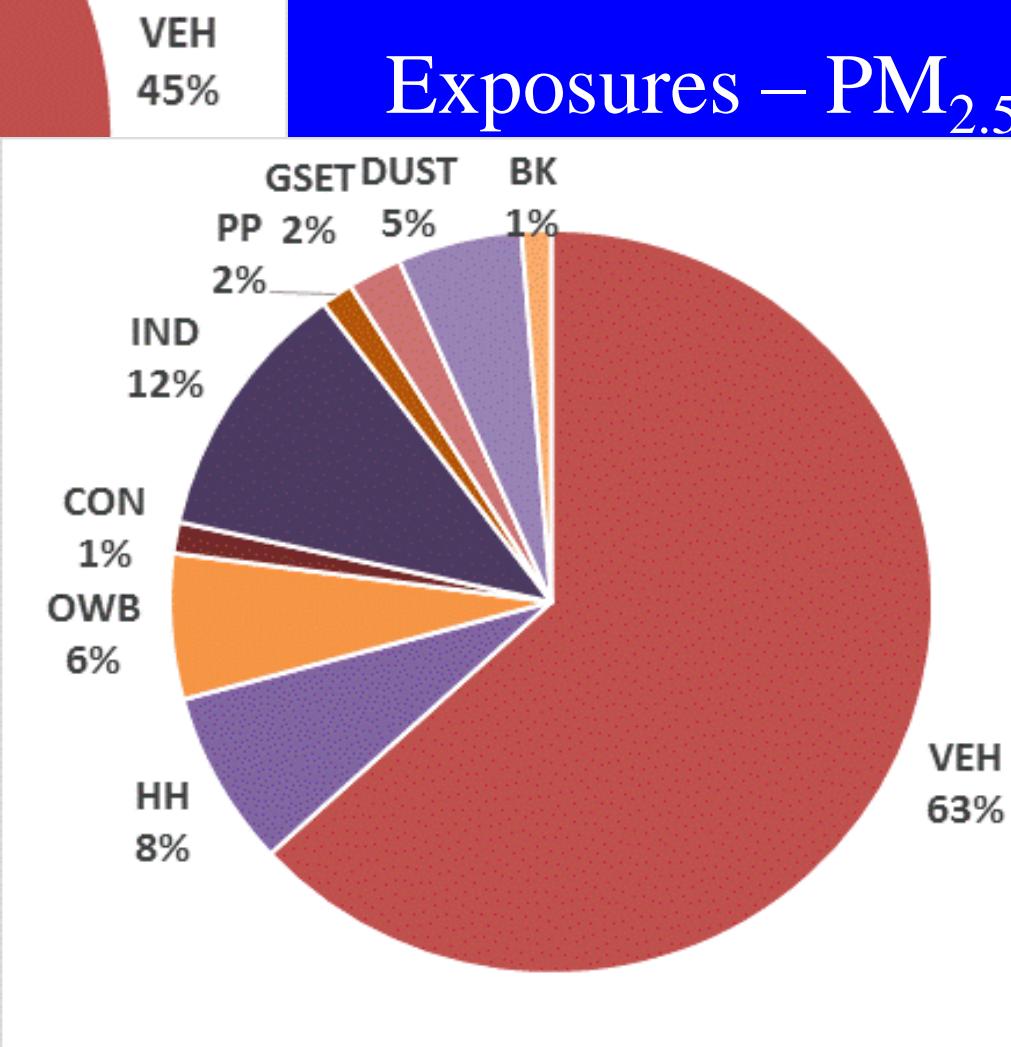
	Average	SD
Waste.burn	109.9	14.6
Veh.exhaust	89.4	11.6
Gen.sets	89.1	14.6
Construction	85.9	10.4
Households	76.3	12.0
Dust	63.2	9.6
Industries	36.9	11.0
Brick.kilns	11.6	17.8
Power plants	8.1	8.4

Emissions – PM_{2.5}
MoHFW Report
estimates by Guttikunda



Chennai-2012

Exposures – PM_{2.5}

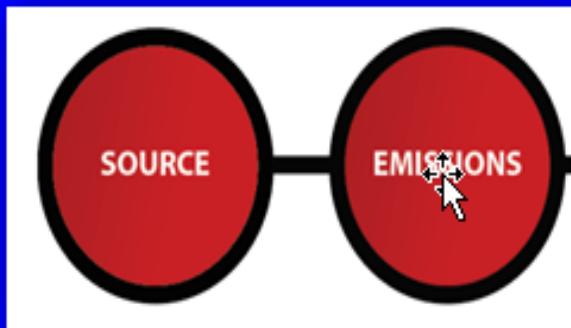


Intake Fraction, cont.

- Nearfield intake fractions not yet as well developed but important for local sources
 - Vehicles
 - Neighborhood waste burning
 - Gen sets
 - Households
- Preliminary estimates of household nearfield intake fractions are about 10x those from ambient (downwind exposures) in Chennai (750 vrs 75 ppm)

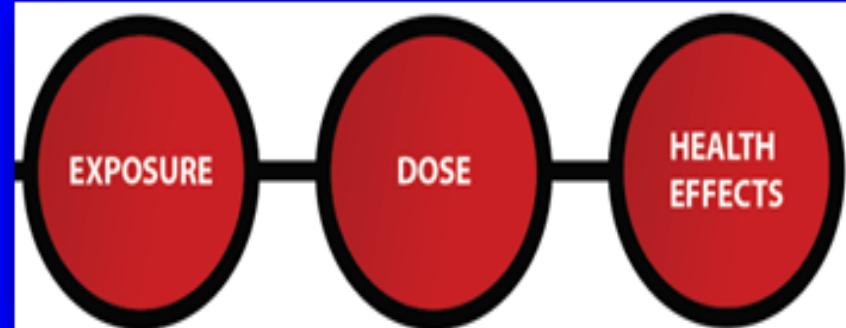
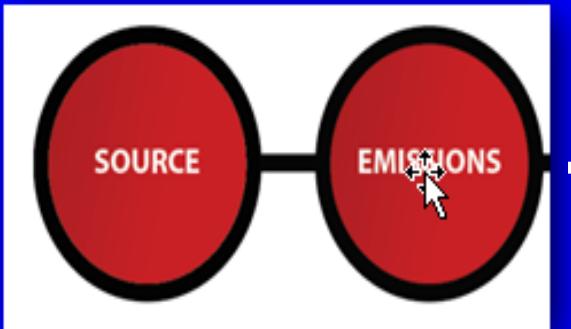
Source – Exposure Relationships

Vehicles

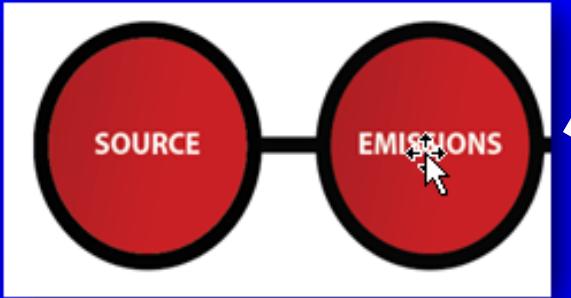


How different?
Does it matter?

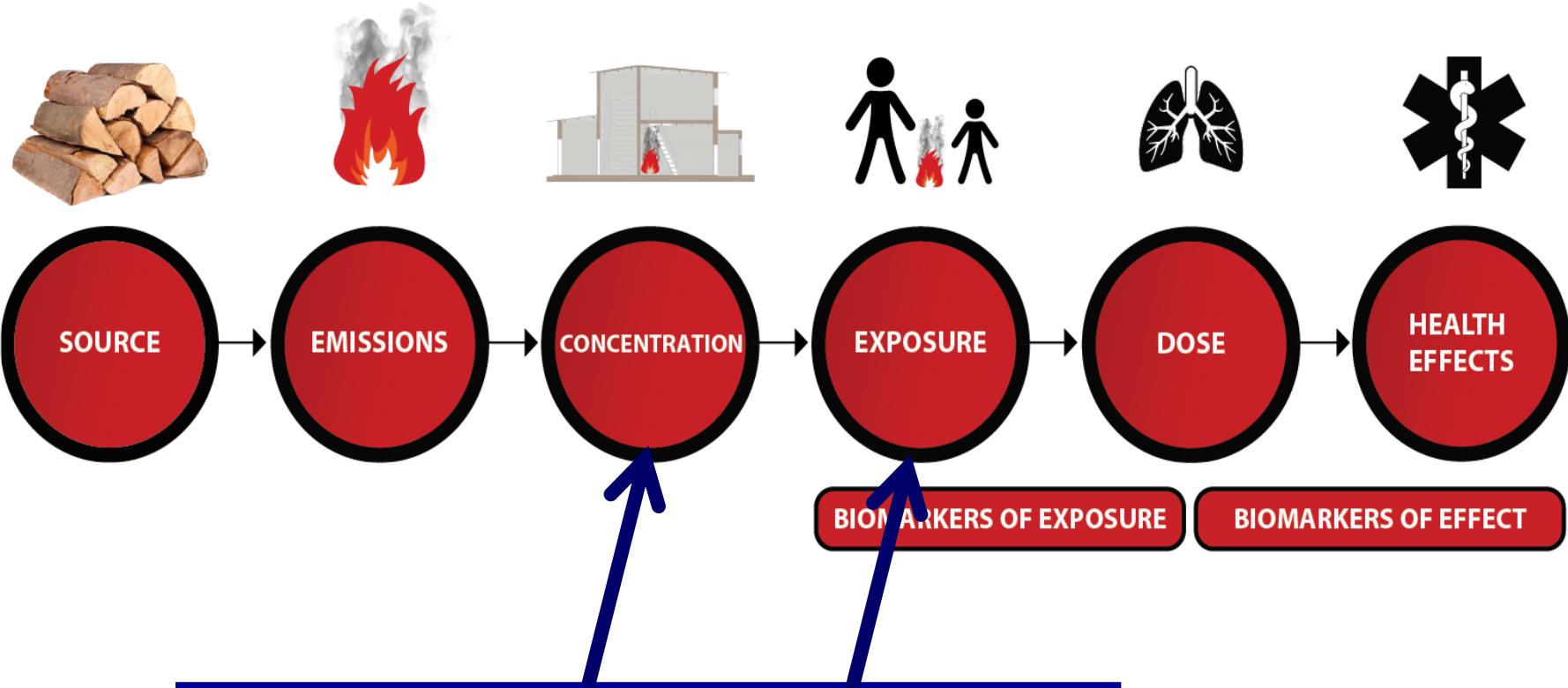
Power plants



Stoves

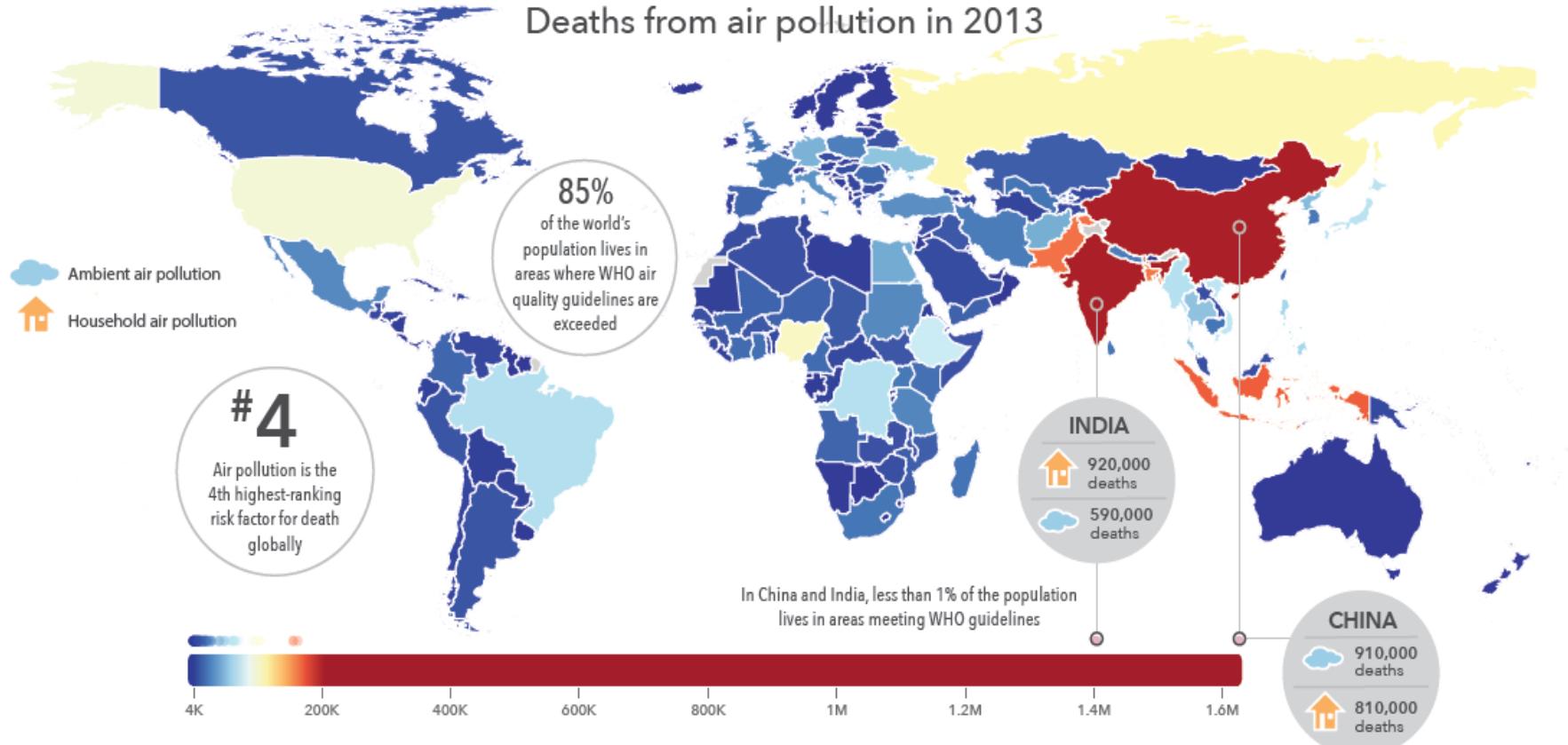


Yes, a factor of
100 different!



Classic air pollution control focuses on more nuanced and efficient control that we sources by their impact on exposure and health rather than environmental quality

Deaths from air pollution in 2013



Air pollution was responsible for 5.5 million deaths in 2013

Household air pollution

Caused by burning solid fuels for heating and cooking, including:



Coal



Wood



Dung

Ambient air pollution

Caused by emissions from things like:



Power generation



Transportation



Agriculture

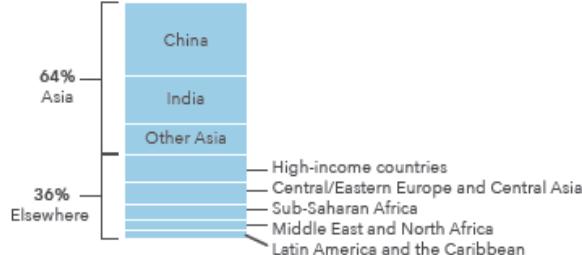


Open burning

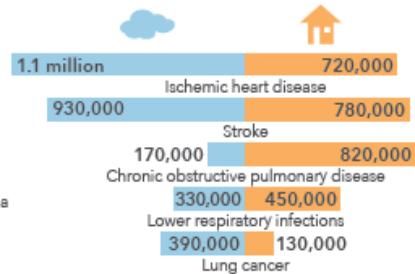


Household air pollution

2.9 million deaths from ambient air pollution in 2013



10% of all deaths were from air pollution in 2013



Source:

- Forouzanfar MH, et al. Global, regional, and national comparative risk assessment of 79 behavioral, environmental, and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*. 2015 Dec 5;386(10010):2287-323.
- Brauer M, et al. Ambient air pollution exposure estimation for the Global Burden of Disease 2013. *Environmental Science & Technology*. 2016 Jan 5;50(1):79-88.



India's situation today not like Europe and North America in the past

- Traditional and modern sources both strong at once
- Population density much higher –what was OK once is not so any longer
- Traditional and modern intermingled – each affect each other
- Understanding of health effects changed
- Scientific methods have evolved

India and Air Pollution, summary

- Not only the highest burden of disease from air pollution in the world, but also among the highest burdens per capita
- Will get worse if current trends continue
- Both ambient and household pollution important
 - And they are connected
 - New approaches to control needed
 - And available

Many thanks
For publications
and presentations:
Just “Google”
Kirk R. Smith

